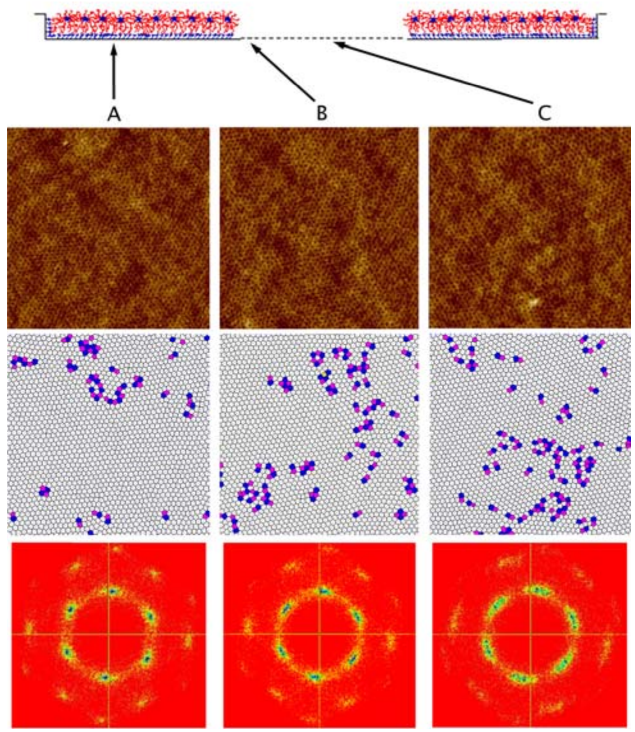
Research Accomplishment: Edge-induced Hexatic Freezing of 2D Block Copolymer Layers

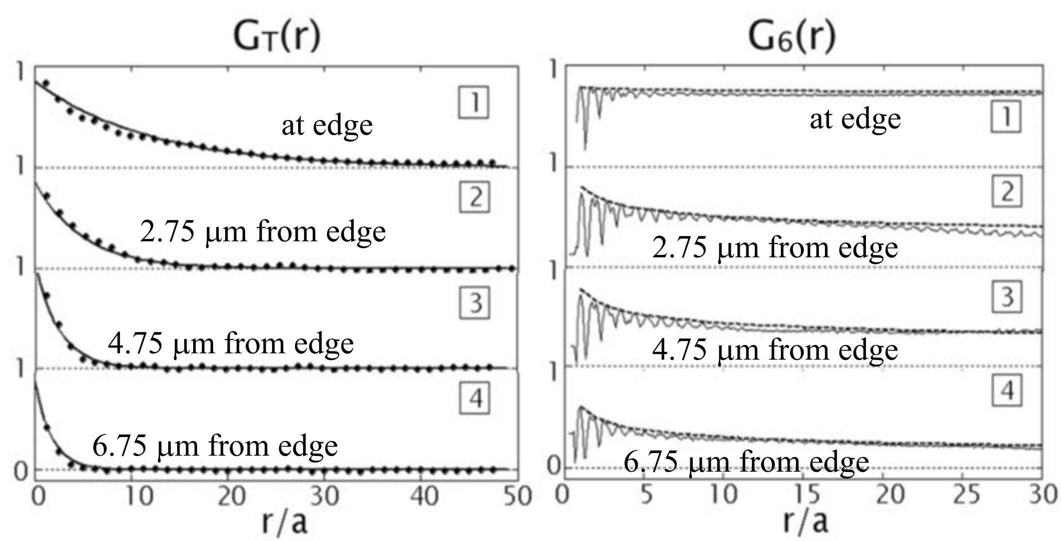
E.J. Kramer (UCSB)

Surfaces of crystals in 3D are known to initiate melting or freezing and under certain circumstances frozen layers of finite thickness form on the surface above the bulk melting point. In 2D the edges of a layer may cause an analogous edge freezing. In two dimensions however the infinite liquid is predicted to first freeze to a hexatic phase which then transforms to a 2D crystal at lower temperature. We observe that a 2D layer of block copolymer spheres confined to a 30 nm deep, 15 μm wide SiO_2 well is a 2D liquid in the center of the well at 255 °C. At the edge however the layer is a hexatic whose translational and orientational order, represented by the correlation functions $G_T(r)$ and $G_6(r)$, decreases slowly from the edge until liquid-like order is obtained in the well center. The density of dislocation defects (pairs of pink and blue polygons in the Voronoi diagram below) increase with distance from the edge in the hexatic and the 2D diffraction pattern shows an increasing azimuthal smearing. These results suggest new processing procedures for achieving 2D block copolymer crystals with improved order for nanopatterning applications



at edge | 2.75 μm from edge | 6.75 μm from edge

translational correlation function | orientational correlation function



Segalman, Hexemer and Kramer, Phys. Rev. Lett, in press.

Broader Aspects of Research Accomplishment

Rachel Segalman

The work on the freezing of 2D block copolymers forms a major part of the PhD thesis of Rachel Segalman. Rachel held a 3 year NSF Graduate Fellowship and was awarded the Corning Fellowship of the Materials Research Laboratory at UCSB for 2002. She was a MRS Award Finalist (2001 Fall Meeting) and received her PhD in Chemical Engineering at the end of 2003. Rachel currently holds a Chateaubriand fellowship from the French government that she won to allow her to be a post-doc with Georges Hadziioannou at the University Louis Pasteur Strasbourg, Ecole Européenne Chimie Polymères Matériaux (ECPM). At the beginning of 2004 she will move to the University of California, Berkeley, where she will become Assistant Professor of Chemical Engineering

Industrial Connections

The 2D crystals of block copolymer grown using edge control are of interest for nanolithographic patterning. Interactions are developing with nanotechnology groups at IBM, GECR&D and Mitsubishi. The work here demonstrates that basic physical processes place important limits on what can be achieved by 2D self-assembly and defines where these become important

David Statti

David Statti is currently a second year student at Allan Hancock Community College in Santa Maria, CA. Last summer as an REU-INSET student at UCSB he investigated the time evolution of block copolymer surface features (islands and holes) on topographically patterned substrates, the results of which highlighted the importance of the surface pattern step-height . He presented his results on campus at the Undergraduate Research Colloquium held Aug. 14, 2003. He plans to enroll at UCSB as a junior in the fall of 2004 and we look forward to his continued participation as a UCSB undergraduate in this research.

David Statti with the hot-stage AFM used for his project.